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Abstract

In this paper we estimate price and income elasticities of demand for housing characteristics using the information of properties appraised in the city of Barcelona (1998-2001). We employ a two-stage approach, estimating hedonic price equations for different districts in order to subsequently estimate the corresponding demand equations. The results allow us to analyse the complementarity or substitutability relationships among the characteristics analysed, and also to catalogue these characteristics as goods. By knowing the price, cross and income elasticities of housing characteristics we can make policy recommendations about the type of housing units which are the most desirable to be subsidized.

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Price and income elasticities of demand for housing characteristics: new empirical evidence for the Spanish case

1. Introduction

Public-sector budget measures for housing can be divided into indirect aid and direct aid. Direct aid appears in the successive housing plans and takes the form of interest rate subsidies, access to qualified loans and personal grants. Indirect aid is that derived from the tax treatment given to the usual home in the Spanish tax system, and which affects the principle of tax neutrality[i].

In Spain 87% of budget aid for housing is allocated to indirect aid to subsidise home purchases, whereas in the European Union this percentage ranges from 10% to 25%, and only in Sweden does indirect aid exceed 50%. This type of public-sector intervention, aimed more at boosting the construction industry than at meeting housing needs, combined with the soaring inflation that has taken place in the housing market in Spain in recent years, has rendered access to housing difficult for certain social groups and has cast doubt on its social function.

A commitment has now been made to shift this imbalance in the public-sector budget towards a greater relative presence of direct aid policies, including, for example, policies for subsidised housing and social renting. Bearing this in mind, if we understand housing as a basket of different attributes that contribute to the provision of housing services, characterising the demand patterns of each of these attributes of housing will give us greater insight into the aspects that influence how housing is valued.

The possibility of distinguishing between which attributes are seen as necessities and which as luxuries, and knowing the substitutability and complementarity relationships among the various attributes, will allow a more thorough understanding of the housing needs of the population, thus facilitating specific direct aid policies.

In this way, using data on properties appraised in the city of Barcelona, we set out to estimate the price and income elasticities of demand for a series of basic housing characteristics (quantity, quality and location). For this study we had access to a very large sample, not only in terms of the number of properties included but also as regards the time span, as the appraisals correspond to the period 1998-2001. The main goal of the paper is, therefore, to make policy recommendations about the type of housing units which are the most desirable to be subsidized, based on the information of price, cross and income elasticities of housing characteristics.

The paper is structured as follows. Section 2 sets forth the theoretical framework for the hedonic price model and for obtaining the demand equations. Section 3 describes the empirical model. Section 4 accounts for the data and the variables used in the estimates, while we discuss the main results in Section 5 and end with some brief conclusions in Section 6.

2. Theoretical framework

The economic literature on hedonic prices arose in the context of the car market. This was the framework for the classical work by *Griliches (1971)*, who popularised these models. In this work, he estimated car prices after controlling for the characteristics that affected their price, such as horsepower or fuel consumption. It is worth noting, however, that he did not “invent” this type of model, or even coin the term “hedonic”. This must be attributed to Andrew Court, with his work in the early 1940s (*Court, 1941*). In fact, these works are rather topical at present, as the functional form of these models is under review.[ii]

Once the technique had been popularised in the 1950s (*Tinbergen, 1951*), it took over a decade to provide it with a theoretical foundation. In this case the classical work was that of *Rosen (1974)*[iii]. In it he showed how heterogeneous products are composed of various characteristics and how the marginal price implicit in these characteristics can be known by estimating a model (hedonic price model) that accounts for the price of a product in terms of its characteristics. Clearly, housing is a good that fits perfectly into the framework of hedonic price models.

One of the applications of the hedonic price models is the estimation of constant quality price indexes. Desirable information to calculate these indexes would be the price for a sample of repeat sales belonging to a representative house. Such samples, as well as promotions and households samples with identical characteristics, allow to the variation in prices of homogenous houses to be obtained. However, given the practical difficulty to get this data, hedonic price models appear as an alternative to the calculation of house price indexes. *Mills and Simenauer*[iv] *(1996)* estimate hedonic price models that allow the comparison of the housing price indexes, over the seven years of their sample of regions. The results show that more than half of the growth in housing prices during this period comes from improvements in the quality. Anyway, *Bover and Velilla (2001)* addressed the estimation of price indexes with a sample of multiunits of housing (a set of houses that share most of the features) that makes it unnecessary to include in the estimation most of the housing characteristics.

Housing is a unique good, i.e., each housing unit is different in some way from all others. Among its characteristics we find: need, durability, spatial immovability, indivisibility, the practical absence of significant futures and insurance markets, information asymmetries, the importance of the rental market as a result of the high cost of purchasing, and above all multidimensional heterogeneity, which fully justifies the use of the hedonic technique.

Following *Rosen (1974)*, and undertaking the characterisation that he makes in his work of the market for heterogeneous goods, the problem is reduced on the demand side to consumer utility maximisation subject to an exogenous budget constraint. The supply of attributes is important to determine the hedonic price, but it is exogenous for any given consumer. The consumer of a heterogeneous good such as housing, with a vector of socioeconomic characteristics α that characterises him or her, obtains utility from a vector of n objectively measurable characteristics[v] $z=(z_1,...z_n)$ and from a non-housing numerary good, x. Therefore, the utility function:

$$U = U(z_1,...z_n, x, \alpha) \qquad (1)$$

is maximised subject to the budget constraint:

$$y = x + p(z_1,...z_n) \qquad (2)$$

where y is income and $p(z) = p(z_1,...z_n)$ is the function that relates prices to the attributes revealed through the implicit markets for the products. The consumers are price takers, taking the functional form $p(z)$ as given and having full information on the parameters of this function. It is important to note at this point that the hedonic price function is not linear, i.e., the consumer can affect the price by varying the quantity consumed of this and/or other characteristics.

Utility maximisation subject to the budget constraint gives rise to the vector of n demand functions for the characteristics:

$$z_i = f(p_{z_1},............, p_{z_n}; y; \alpha) \qquad (3)$$

where p_z is the vector of the first derivatives of the hedonic price function $p(z)$ with respect to its arguments.

$$p_{z_i} = h(z_1,.......z_n) \tag{4}$$

If we focus on the demand functions, *Rosen (1974)* proposes a two-stage estimation method:

- The first stage comprises the hedonic estimation, i.e., that which relates the prices of housing to its characteristics, in order to subsequently compute by derivation a set of implicit marginal prices, the hedonic prices, p_{z_i}.

- The second stage serves to estimate the demand equations for each of the housing characteristics using the hedonic price estimates reached in the previous stage. Additionally, a vector of the household's sociodemographic variables α (observed heterogeneity) is usually included, together with its income level y.

The ultimate objective of this second stage is to obtain the price and income elasticities of the various housing characteristics. One problem with this model that is addressed in the literature economic is the identification between the price function and the demand function. In the absence of additional constraints, the second-stage estimate may merely reproduce the information already provided by the first stage. The problem, analysed by *Brown and Rosen (1982)* and *McConnell and Phipps (1987)*, among others, is avoided only if the coefficients of the marginal price function for z_i cannot be expressed as an exact combination of the coefficients of the demand functions. The solution, therefore, consists in specifying the price function in such a way that an exogenous factor is introduced into the marginal price, thus enabling us to identify the demand functions. As a result, the empirical literature tends to solve the problem using data from several markets in space or time, leading to the calculation of a hedonic function in each market and a single demand for all markets. In this way, in practice, several markets are required to estimate one single demand equation. Alternatively, *Brown and Rosen (1982)* propose specifying demand equations of order m for the characteristics, and at the same time a hedonic price equation of order m+2 or higher for the characteristics, such that the implicit marginal price equations will be of order m+1 or higher, solving the identification problem mentioned earlier. However, *Ekeland et al (2002 and 2004*) consider that the demand parameters are always identified in single market data if the marginal price function is nonlinear, which they call a "generic property of equilibrium in the hedonic model". Semiparametric estimation (as in *Bin, 2005*) or instrumental variables estimation is proposed. Finally, *Rouwendal (1992)* introduces an alternative to the two stage procedures proposed by *Rosen (1974)*. The author models the hedonic price function explicitly as the envelope of a family of bid-rent functions.

3. Empirical model

On the basis of the considerations discussed in the section above, we will divide the methodological approach into two parts: the modelling of the hedonic price regression and the modelling of the demand equation. Following the proposal of *Brown and Rosen (1984)*, we will assume a certain amount of segmentation in the housing market. That is to say, the parameters of the hedonic price function will be the same within each market segment and different between segments. By market segments we mean different geographical areas, so that price variations are caused either by variations in the conditions of the supply or by different distributions of preferences over areas, and therefore price variations are exogenous to the consumers. Consequently, different hedonic price equations will be estimated for each segment, but one single demand equation will be estimated for each characteristic for the whole of the housing market (unsegmented).

As regards the modelling of the effect of the characteristics and the area on price, the hedonic price function specified is linear, and hence so is the budget constraint; consequently the demand equations will be well defined, and additional nonlinearities as a result of the nonlinearity of the budget constraint will be avoided[vi]. Furthermore, the linear specification does not suffer from endogeneity problems in the implicit marginal prices that would result from using another specification, given that these prices depend on the quantity consumed of each characteristic[vii].

The econometric model to estimate corresponding to the hedonic price equation would have the following form:

$$p_i = \sum_k p_{H,k} H_{i,k} + \sum_j p_{L,j} L_{i,j} + u_i \qquad (5)$$

where p_i is the price of housing unit *i*, $H_{i,k}$ is the *k*th physical characteristic of housing unit *i*, and $L_{i,j}$ is the *j*th characteristic of the area to which housing unit *i* belongs, while $p_{H,k}$ and $p_{L,j}$ are the prices of the *k* characteristics and the area respectively (parameters to estimate) corresponding to a segment (district or year) y, and u_i is the error term. If the segmentation is done by districts in equation (5), dummy variables are included for the years of the period considered in order to capture the time trend in housing prices.

In turn, the second stage consists in estimating a system of demand equations for housing characteristics. Following *Parsons (1986)* and *Bilbao (2001)*, we chose a system of AIDM-type Marshallian demand equations expressed as a proportion of the budget:

$$w_k = \alpha_k + \sum_j \gamma_{kj}\, log\ p_j + \beta_k\, log(\ x / P\ ) \qquad (6)$$

where w_k is the proportion of the total expenditure that is allocated to characteristic *k* ($w_k = p_k H_k / x$, H_k being the quantity demanded of characteristic *k*), α_k, γ_{kj} and β_k are parameters, p_j is the price of characteristic *j*, *x* is the total expenditure allocated to housing characteristics, given that a weak separability assumption is made between housing characteristics and other goods, and *P* is a price index approximated by a price index previously fixed as that proposed by Stone: $\log p = \sum w_k \log p_k$, where p_k are the prices of the characteristics.

When estimating the AIDM demand system, the usual budget constraints of aggregation ($\sum_{k=1}^{n}\alpha_{kj}=0\ \sum_{k=1}^{n}\gamma_{kij}=0\ \sum_{k=1}^{n}\beta_{kj}=0$), homogeneity ($\sum_{j}\gamma_{kj}=0$) and symmetry ($\gamma_{kj}=\gamma_{jk}$) are imposed. It is therefore a system of demand equations in which the total sum of the proportions of expenditure is equal to unity ($\sum w_k = 1$), that are homogeneous of degree 0 in prices, and that satisfy the symmetry conditions, these equations being linear.

4. Data and variables

The sample used in this paper comprises 9,297 observations of housing in the city of Barcelona corresponding to the period 1998-2001. As such, the sample has a certain temporal dimension but on no account can be taken as panel data because the properties included in each yearly subsample are different.

The data, duly refined, come from an annual representative sample taken by the appraisal firm TINSA. They contain a great variety of physical characteristics of the housing, together with information about the area of the city to which each property belongs. The prices are therefore appraisal prices[viii]. Specifically, they are appraisals conducted with the same criterion as official appraisals according to Order ECO/805/2003 (market value) to be used for certain financial purposes (basically, the valuation of the house as important information in order to grant a mortgage loan).

With regard to the definition of the variables used, the dependent variable is as follows:

Total value: total value of the property in euros

Whereas the explanatory variables are:

Floor area: floor area in square metres, including a proportional part of the communal areas

Year: dummy variables defined according to the year to which each observation belongs

Age: seven dummy variables in ascending order according to age, for the following categories: new housing; aged 1 to 5 years; 6 to 10; 11 to 20; 21 to 30; 31 to 50; and over 50

Lift: dummy variable with the value 1 or 0 depending whether or not the property has a lift

Floor: four categories have been defined with their corresponding dummy variables depending whether the property is ground floor or basement; first floor; second floor; or third floor or higher

Attic: dummy variable that takes the value 1 if the property is an attic and 0 otherwise

Street: dummy variable that takes the value 1 if the property faces the street and 0 if it faces a courtyard

Heating: dummy variable that takes the value 1 if the property has heating and 0 otherwise

State: state of repair of the property; five dummy variables corresponding to each of the five evaluations of the state of the property (very bad, bad, average, good and very good)

Renovation: time elapsed since last renovation work, with four dummy variables corresponding to the four intervals for which this variable is defined: if the property was renovated in the year of the sample or the five previous years; 6 to 10 years previously; 11 to 20 years previously; or over 20 years previously

Areas: statistical area (248) in which the property is located

Table A.1 in the Annex shows the mean value of the characteristics (except for the area) for each of the years of the sample. It is easy to see that most of the sample is used housing, recently renovated, and with an average floor area of around 85 sq m.

5. Results

The first stage consists in estimating the function that relates prices of housing to its characteristics. As mentioned earlier, the functional form will be linear and the variable to be explained will be the total value of the housing. Furthermore, in order to avoid arriving at negative prices and also to simplify the results, the dummy variables that refer to location have been replaced by the variable "educational level". This is justified because in *Garcia et al (2006)*, by estimating a hedonic price model (nonlinear at levels) with the same database, it is shown how the variability of the coefficients of the dummy variables referring to location (statistical area) is explained almost solely by the variable "educational level" (correlation close to 0.9). This variable is measured as the average number of years spent in formal education by the inhabitants of any given area. According to the theories of human capital and the available empirical evidence, this type of variable approximates the average income of the inhabitants of the area. As indicated in *Garcia et al (2006)*, this high correlation showing greater willingness to pay in areas with a higher educational level (or higher income) can be explained by the fact that these variables (income or educational level) may be correlated with other types of factors that individuals value when choosing the area in which they wish to live.

The coefficients accompanying each characteristic are marginal prices (which coincide with the average prices of each characteristic). As was made clear earlier, although we only have data for the city of Barcelona, we have sufficient observations for almost all the districts (geographical areas with sufficient internal heterogeneity) to encounter no problem in estimating hedonic price functions by districts, and thus in obtaining the necessary variability in marginal prices to be able to identify their effect on the estimation of the system of demand equations. This segmentation by districts is the first one to be used, each of the equations being estimated separately for each district (10) by OLS; the results are presented in Table A.2 in the Annex.

The economic literature has focused, by means of capitalization, on the willingness to pay of some neighbourhood amenities such as parks, schools or undergrounds. In this framework, we can emphasize the contributions of *Cheshire and Sheppard (1995), Bell and Man (1996), Bilbao-Terol (2000), Bogart and Cromwell (2000), Haider and Miller (2000), Gibbons and Machin (2001), Downes and Zabel (2002) Tse (2002), Anderson and West (2006), Cheshire and Sheppard (2004).* However, the main aim of this paper is not to explain variability in housing prices due to the location but to estimate the price and income elasticities of demand for a series of basic housing characteristics (quantity, quality and location), so we decide to replace the amenities variables for the locational dummies. In fact, the elasticities parameters estimated from a model with these amenities as a explanatory varaibles remain identical and can be obtained by request to the authors. To see the effect of many amenities to the house price with the same dataset you can see *Garcia et al (2006)*

The explanatory power of the models estimated is similar to, and even seemingly greater than, that of the models presented in *Garcia et al (2006)*. In fact, the adjusted R^2s stand at around 85%. This is due, firstly, to the fact that the dependent variable is the total price[ix] of the property rather than the price per square metre, therefore the variability of the dependent variable changes (is greater) and this influences the R^2 value, and secondly to the fact that in *Garcia et al (2006)* the dependent variable is the log of the price per square metre, a transformation that reduces the variability of the dependent variable, which also influences the R^2 value. As far as the effects of the different explanatory variables are concerned, the patterns fit those presented in *Garcia et al (2006)*, albeit with differences of magnitude and significance among segments; the only exception is the effect corresponding to the fact of having or not having heating, which has an unexpected sign. This is a consequence of the different specification as regards the functional form (linear in this case and pseudo-logarithmic in *Garcia et al*, 2006)[x], and also the fact of approximating the effect of location through the average years of formal education in each statistical area, whereas in *Garcia et al (2006)* dummy variables are used for 89 groupings of the 248 statistical areas existing in the city of Barcelona. Nevertheless, this linear specification is preferred, as it avoids the above-mentioned endogeneity problems of marginal prices in the system of characteristic demand equations.

Once the prices implicit in each housing characteristic have been obtained, the demands for the characteristics are estimated. As reflected in equation (7), the dependent variables in the AIDM are defined as the proportion of expenditure that each household sets aside for each characteristic and are grouped into the following three categories. Therefore, a demand system is estimated with three equations:

- Proportion of expenditure on quantity of housing (w_1) is defined as the number of square metres of a property, by the price per square metre in the year to which the property belongs, divided by the total expenditure on housing characteristics, which is simply the sum of the expenditures on the three characteristics considered (quantity, quality and location).

- Proportion of expenditure on quality of housing (w_2) is defined using the method applied in *King (1976)* and *Erekson et al (1979)*, which consists in grouping together characteristics related to the quality of housing. Thus, expenditure on quality is the sum of the products of the price of each of the characteristics related to quality (age, heating, lift, floor number, whether it faces the street, state of repair, and time elapsed since last renovation work) in each market by the level of each of them chosen by each household[xi], dividing the sum of these products by the total expenditure.

- Proportion of expenditure on location (w_3) is calculated as the product of the price of this characteristic in each market by the years spent in formal education by the average individual belonging to a particular area or year, divided by the total expenditure.

The mean values of these proportions are very similar, regardless of whether we use marginal prices estimated by districts. Thus, in the segmentation by districts the proportions of expenditure corresponding to quantity, quality and location are 49.86%, 14.48% and 35.66%. The weight of location is reflecting the importance of this variable in accounting for housing prices[xii].

As explanatory variables of the demand equations we should include price indices for the various housing characteristics (p_j), and real income or expenditure (x/P), with the aim of calculating the corresponding price and income elasticities. To this effect, the explanatory variables included in the equations, all of them expressed in logs, are:

- The hedonic prices of floor area (quantity price index) and educational level (location price index) calculated in the previous stage.

- The price index for housing quality (quality price index) expressed in natural logarithms. In order to define this index we take a standard property, which in our case is the average housing unit for the city of Barcelona in the period 1998-2001. The characteristics of this average housing unit are calculated by taking an average of the housing characteristics weighted by its weight in the sample. Lastly, the quality price index for each district or year is the sum of the products of the hedonic prices of each of the characteristics that comprise the quality, by the level fixed as standard[xiii].

- The total real expenditure, expressed as the quotient between the total budget and Stone's price index as defined above.

The model is estimated using a Seemingly Unrelated Equations (SURE) procedure, which holds two advantages over OLS estimation: we gain efficiency by considering the contemporary correlation between the errors of several equations and we can contrast the symmetry hypotheses of the parameters. Given that the sum of the proportions of expenditure on the three characteristics is equal to 1 for all the observations, the estimate is made by removing one of the equations, in this case the one corresponding to expenditure on location, in order to avoid the problem of the singularity of the error variance-covariance matrix as a consequence of the aggregation condition mentioned earlier.

Two alternative models are estimated. In the first model the property market is segmented by districts, while the second model takes into account the possible effect that the sociodemographic characteristics of the individuals may have on the demands analysed. To this end, in view of the unavailability of individual data on the characteristics of buyers, we use a set of sociodemographic variables of the various districts, obtained using Barcelona City Council population statistics (*model with segmentation by districts and sociodemographic characteristics*). The variables included in the specification and recorded at district level are: proportion of women, proportion of young people (aged under 24), proportion of individuals with university studies, proportion of permanent employees and proportion of business owners.

Table 1 presents the estimates of the demand equations, imposing homogeneity and symmetry conditions for the two models considered. As is standard practice in studies estimating systems of demand equations, null hypotheses associated with the homogeneity and symmetry conditions are rejected at the usual significance levels. The goodness of fit is high, and all the variables relating to prices and expenditure are individually significant at 1% for all three specifications. The cross coefficients of the estimate indicate patterns of substitutability between quantity and quality (positive sign) and of complementarity between quality and location, and also between quantity and location (negative sign).

[TABLE 1]

Table 2 reports the income elasticities, $\hat{\varepsilon}_r = \left[\frac{\hat{\beta}_i}{w_i}\right] + 1$, and price elasticities, compensated[xiv], $\hat{\varepsilon}^*_p = \left[\frac{\hat{\gamma}_{ii}}{w_i}\right] - 1$, and uncompensated[xv], $\hat{\varepsilon}_p = \hat{\varepsilon}^*_p - \hat{\beta}_i - w_i$, of housing demand for each of the three characteristics considered and for each of the two models.

The estimated[xvi] income elasticities classify quantity as a luxury good (elasticity greater than 1), whereas quality and location are considered as necessary goods (although the latter shows an income elasticity that is closer to unity). This may be reflecting a usual result, both in the descriptive information and in the more detailed estimates of hedonic price models, insofar as the price per additional square metre is higher for small properties than for larger ones[xvii]. It should also be stressed that the magnitude of the estimated income elasticities is very similar for the two specifications used (with and without adding demographic variables). Furthermore, the price elasticities, both compensated and uncompensated, appear with the expected negative sign, in accordance with the decreasing relationship between price and quantity demanded of the characteristics. Although in this case the differences between the estimated elasticities depending on the specification considered, are greater than in the case of the income elasticities, some patterns are also repeated regardless of the model analysed, and are worth mentioning. Thus, location presents a more inelastic demand than the other two characteristics considered, while quality presents a compensated price elasticity of around –1, and in the case of floor area (quantity) demand is clearly inelastic, although less so than in the case of location. Compensated price elasticities are in all cases greater in absolute value than the corresponding uncompensated ones, as a consequence of the income effect they reflect, and the demands relating to quality and quantity can be considered perfectly elastic.

[TABLE 2]

As indicated earlier, we estimated a version of the model with segmentation by districts that includes as explanatory factors information on the sociodemographic characteristics of the districts of the city of Barcelona. The results of the model are also presented in Table 1, and the corresponding elasticities in Table 2.

It should be noted that the proportion of expenditure on quantity (floor area) increases with the proportion of young people in the district, whereas it decreases with the proportions corresponding to the other characteristics considered. Furthermore, the proportion of expenditure on location increases with the proportion of permanent employees and business owners, showing greater interest (preferences) in this type of characteristic among these occupational groups.

To sum up, the classification of the housing characteristics based on its income elasticity shows us quantity as a luxury good, whereas quality is considered as a necessary good and location a good with an elasticity close to 1. That is, an increase in the income of the citizen results in a less than proportional increase in the quantity demanded of the characteristic “quality”, more than proportional increase in the quantity demanded of the characteristic “quantity” and almost proportional in the quantity demanded of the characteristic “location”. In terms of policy making, given the former demand patterns obtained, the housing needs of the population are small subsidised housing units keeping certain minimum standards of quality and location. However, if the key segment of this policy is young people the result should be matised, because young people show greater preference in quantity.

Moreover, the compensated price elasticities indicate inelastic demands for all the characteristics, ie, an increase in the price of one of the characteristics results in a less than proportional decrease in the quantity demanded of that characteristic, especially in the case of location.

6. Conclusions

In this work we have obtained demand equations for housing characteristics grouped into three categories: quantity (floor area), quality (recorded through variables relating to the state of repair of the property, renovation work done and other factors) and location, with the main aim of getting to know society's housing needs in order to make policy recommendations about the type of housing units which are the most desirable to be subsidized. In this context, we were extremely interested in knowing the sensitivity of the quantity demanded of a characteristic to variation in its price (price elasticity), variation in the price of another characteristic (cross elasticity) or variations in income (income elasticity).

To this end we have estimated hedonic equations for each of the districts of the city of Barcelona and for each of the four years corresponding to the transactions considered. The hedonic equations have yielded the evaluations (implicit marginal prices) of each of the housing characteristics in each district, together with the differences in the appraisal of a property. Thus, two households with the same income living in the same town and but different districts will have to make a different economic effort to purchase a home with similar characteristics[xviii].

In the second stage, we have estimated demand equations for the three characteristics mentioned for the district, which enables us to complete the specification with the inclusion of sociodemographic variables.

Furthermore, it has been observed that the compensated price elasticities indicate inelastic demands. Thus, keeping expenditure and the rest of the prices constant, an increase in the price of one of the characteristics results in a less than proportional decrease in the quantity demanded of that characteristic. In other words, in economic policy terms, in the face of increases in the price of all the housing characteristics, citizens will opt to distribute their budget in such a way as to cause minimum losses in terms of location with respect to their initial desire, at the expense of greater losses regarding the size and quality of their home. Obviously, if citizens can keep their utility constant, an increase in the price of floor area will also lead to a less than proportional decrease in the quantity demanded of floor area. This, given the substitutability and complementarity relationships obtained, will also lead to a decrease in the quantity demanded of location and will be offset by an increase in the quantity demanded of housing quality.

Both the patterns of substitutability and complementarity and the income and price elasticities (compensated and uncompensated alike) yield similar results to those obtained in other similar studies.

Demand models of differentiated goods, such as the one presented here for housing, are frequently used as instruments for the analysis of public policies. In this case, in view of the comments made above, a policy of small subsidised housing units is justified, although with certain minimum standards of quality and in no event in marginal areas, given the demand patterns obtained. In particular, with regard to differences between population groups, young people and women seem to focus their demands on quantity and quality, probably because of the impossibility of obtaining a good location. In contrast, permanent employees and business owners focus their demands on the desired location. Notwithstanding, demand models of differentiated goods are a first step towards a specific evaluation of public goods and public policies in the sector through simulations.

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[i] Action by the Spanish public sector in terms of housing policy is described in depth in *Rodríguez López (1990)*, *López García (1992)*, *Pareja and San Martín (1999)* and *García Montalvo and Mas (2000)*. In particular, *Pareja and San Martín (2002)* describes action by the Spanish public sector affecting the decision as to which tenure system individuals should adopt.

[ii] For a detailed analysis of Andrew Court's work and the reasons why his technique was neglected for more than two decades, see *Goodman (1998)*.

[iii] The hedonic technique rests on modern consumer choice theory, according to which the consumer derives utility not directly from the good but from its characteristics. See *Lancaster (1966)*.

[iv] See, *Englund, et al (1999)* and *Chun, et al (1998)*, among others, as examples of this literature.

[v] As we will see presently, sometimes socioeconomic variables are also included in order to control for consumer heterogeneity or fiscal variables, with the aim of testing some hypothesis of public intervention.

[vi] The literature on labour supply models is a good example of the implications of nonlinearity of the budget set in terms of estimation of leisure demand equations (labour supply), and also of the consequences of linearising nonlinear budget sets. See *García and Suárez (2003)* for a discussion of the empirical importance of these aspects.

[vii] The most common solution to this endogeneity problem has been to use sociodemographic variables as instruments (*Palmquist, 1984*).

[viii] It should be stressed that the sample used is a selected sample, i.e., a sample of potentially salable properties; indeed, this is why they were valued. In this study this has not been taken into account when estimating the hedonic price model. The evidence provided by *Jud and Seaks (1998)* shows that in that particular case the problem of sample selection had little effect on the results.

[ix] The price per square meter is a more correct specification of the dependent variable when the aim is to capture the variability in one market (*Garcia, et al, 2006*). However, as Parsons (1986) pointed out, the correct specification of the dependent variable and the functional form is not important when the aim is variability between markets, as it is in

this paper. Moreover, the total value and a lineal specification avoid simultaneity and identification problems as well as make interpretation of the results in terms of implicit prices easier, since all the characteristics have a positive coefficient and, therefore, are goods.

[x] Note that in *Garcia et al (2006)* the dependent variable is the log of the price per square metre and the floor area appears in an explanatory variable with the definition $ln\left[\frac{S}{1+S^{\theta}}\right]$, where S is the floor area and θ a parameter that, if equal to 0, corresponds to a model with constant area elasticity.

[xi] In the case of *Erekson et al (1979)* the expenditure on quality is obtained by the difference between the total value predicted by the hedonic equation, expenditure on floor area and expenditure on location.

[xii] In *Garcia et al (2006)* the contribution of location to explaining the variability of price per square metre is quantified as representing 53.58% of the explained variation.

[xiii] In this second stage the observations corresponding to District 4 (Les Corts) were removed because it was the least representative sample (347 observations) and because the price index calculated for some observations was negative.

[xiv] Keeping the utility and the rest of the prices constant.

[xv] Keeping the expenditure and the rest of the prices constant.

[xvi] The evidence provided is robust to alternative market segmentation (segmentation by year), which can be estimated because of the certain temporal dimension of the database. The estimation results and the elasticites are very similar between segmentations and can be obtained from the authors upon request.

[xvii] See *Garcia et al (2006)* for the econometric evidence.

[xviii] *Garcia et al (2006)* provides a detailed analysis with some conclusions on urban economics, explaining price differences between areas in terms of their characteristics.

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Table A.1: Mean of the characteristics in the period 1998-2001

	1998	*1999*	*2000*	*2001*
Floor area	86.02	83.97	84.42	85.86
Heating	0.326	0.353	0.351	0.625
Street	0.829	0.855	0.846	0.827
Lift	0.642	0.605	0.590	0.590
Age				
New	0.032	0.030	0.043	0.034
1-6 years	0.026	0.016	0.020	0.026
6-10 years	0.020	0.016	0.023	0.013
11-20 years	0.171	0.126	0.087	0.073
21-30 years	0.327	0.316	0.292	0.260
31-50 years	0.208	0.246	0.279	0.294
Over 50 years	0.215	0.249	0.256	0.298
State				
Very bad	0.002	0.170	0.003	0.023
Bad	0.040	0.297	0.052	0.068
Average	0.613	0.367	0.639	0.614
Good	0.315	0.119	0.276	0.231
Very good	0.030	0.047	0.031	0.061
Renovation				
0-5 years	0.455	0.433	0.415	0.448
6-10 years	0.167	0.176	0.173	0.162
11-20 years	0.165	0.167	0.173	0.159
Over 20 years	0.180	0.194	0.196	0.188
Floor				
Ground	0.046	0.051	0.061	0.070
First	0.133	0.167	0.136	0.147
Second	0.157	0.174	0.177	0.180
Third or higher	0.607	0.497	0.508	0.545
Attic	0.055	0.109	0.115	0.055

Table A.2: Estimated hedonic price equations by districts
Dependent variable: total value (euros)

	District 1		*District 2*		*District 3*	
	Coefficient	*"t"*	*Coefficient*	*"t"*	*Coefficient*	*"t"*
Floor area	1033.056	(44.84)	1518.175	(64.35)	1227.032	(45.70)
Heating	-7005.169	(2.53)	-8063.990	(4.24)	-4624.932	(3.41)
Street	1508.631	(0.65)	1169.263	(0.61)	-354.387	(0.28)
Lift	26655.854	(9.84)	5357.320	)2.39)	4547.853	(3.10)
Educational level	3138.900	(3.24)	9573.065	(8.59)	9713.888	(10.14)
Year (ref.: 1998)						
1999	24590.530	(9.94)	30067.151	(12.55)	21715.246	(14.60)
2000	39836.477	(18.01)	59571.929	(26.85)	39775.828	(27.61)
2001	61303.235	(20.41)	93757.888	(40.76)	61904.247	(40.01)
Age (ref.: >50 years)						
New	13455.273	(1.80)	34089.407	(6.53)	21727.784	(5.23)
1-6 years	-33690.725	(2.64)	21244.732	(3.49)	7767.997	(2.10)
6-10 years	17009.171	(1.55)	25004.688	(3.26)	15744.275	(4.00)
11-20 years	-441.029	(0.06)	14560.564	(4.86)	7119.313	(3.49)
21-30 years	-3158.012	(0.70)	8834.878	(3.85)	5867.687	(3.42)
31-50 years	-1658.018	(0.55)	2489.116	(1.11)	806.348	(0.53)
State (ref.: very bad)						
Bad	13453.121	(4.55)	13408.640	(3.49)	7590.386	(2.56)
Average	16467.912	(5.41)	17753.669	(4.63)	16464.967	(5.60)
Good	28784.116	(7.44)	27906.759	(6.53)	25396.596	(7.90)
Very good	36644.525	(5.32)	47441.792	(8.40)	37496.304	(8.56)
Floor (ref.: ground)						
First	3879.179	(0.77)	8638.635	(1.24)	1720.541	(0.63)
Second	4903.844	(1.01)	7907.102	(1.15)	2175.580	(0.82)
Third or >	5700.149	(1.22)	13325.130	(2.00)	4882.761	(1.94)
Attic	916.725	(1.62)	20018.175	(1.93)	1971.686	(0.44)
Lift*attic	-14117.636	(1.82)	2589.118	(0.29)	4679.084	(1.06)
Renovation (Ref.: >20)						
0-5 years	8117.726	(3.74)	10795.896	(4.69)	5033.500	(3.20)
6-10 years	2051.591	(0.77)	7026.937	(2.57)	1871.377	(1.04)
11-20 years	2866.822	(1.16)	1887.911	(0.74)	1260.809	(0.70)
Constant	-75912.577	(8.03)	-186623.292	(13.65)	-138093.019	(14.40)
Adjusted R^2	0.85		0.85		0.84	
σ	20.599		2.969		17.024	
Sample size	772		1513		1225	

Table 1: Characteristic demand equations

Model with segmentation by districts

	Quantity		*Quality*		*Location*
	Coefficient	*"t"*	*Coefficient*	*"t"*	*Coefficient*
Price index					
Quantity	0.157	131.27	0.048	51.09	-0.205
Quality	0.048	51.09	-0.007	5.15	-0.041
Location	-0.205	184.95	-0.041	32.79	0.246
Real expenditure	0.166	150.31	-0.112	76.63	-0.054
Constant	0.187	33.35	0.591	87.22	-0.778
R^2	0.880		0.574		
σ	0.038		0.048		

Model with segmentation by districts and sociodemographic variables

	Quantity		*Quality*		*Location*
	Coefficient	*"t"*	*Coefficient*	*"t"*	*Coefficient*
Price index					
Quantity	0.101	52.83	0.080	60.80	-0.181
Quality	0.080	60.30	0.017	7.76	-0.097
Location	-0.181	80.88	-0.096	40.47	0.278
Real expenditure	0.210	199.13	-0.108	73.60	-0.102
Sociodemographic variables					
% young people	0.533	4.68	3.917	28.79	-4.450
% women	-0.508	3.01	4.384	18.99	-3.876
% with higher education	-0.064	1.27	0.986	14.40	-0.932
% permanent employees	-0.691	10.68	-1.717	20.58	2.408
% business owners	-0.391	3.14	-3.683	22.95	4.074
Constant	0.583	7.74	-1.130	10.37	0.547
R^2	0.922		0.649		
σ	0.031		0.043		

Table 2: Elasticities of demand

Model with segmentation by districts

	Quantity	*Quality*	*Location*
Income elasticity	1.36	0.24	1.27
Compensated elasticity	-0.63	-0.58	-0.22
Uncompensated elasticity	-1.34	-0.61	-0.68

Model with segmentation by districts and sociodemographic variables

	Quantity	*Quality*	*Location*
Income elasticity	1.421	0.254	0.714
Compensated elasticity	-0.797	-0.883	-0.220
Uncompensated elasticity	-1.506	-0.918	-0.475